REMARKS

This response is being submitted within six months of the mailing date of the Office Action outstanding. Accordingly, Applicant submits herewith a Request for Time Extension of three months, extending the time for response to Monday, August 26, 2002.

By this Response, claim 1 has been amended. Claims 3 and 13-20 have been cancelled. Claim 1 has been amended to add the limitation of dependent claim 3 as filed. New claims 21 and 22 have been added. New claim 21 recites that the barrier metal layer is subjected to "a non-reactive atmosphere" to form the pre-treated barrier metal layer. Claims 1-2, 4-12 and 21-22 are pending in the application. Claims 1, 9 and 21 are in independent form. No claim fees are required for this amendment.

In a telephone conference between the Examiner and David C. Ripma, attorney of record, on February 19, 2002, a provisional election was made without traverse to prosecute the invention on claims 1-8 and 9-12. Claims 14-20 were withdrawn from consideration by the Examiner. Affirmation of the election of claims 1-8 and 9-12, made on February 19, 2002, is hereby confirmed.

Based on the Office Action dated February 26, 2002, there appears to be some confusion as to the status of claim 13. On the Summary page of the Office Action dated February

26, 2002, the Examiner states that claims 1-12 are rejected and that claim 13 is objected to. On page 2 of the Office Action the Examiner states that Applicants are required to rewrite the claim in independent form. However, the Examiner appears to state that claim 13 should be included in the Restriction Requirement of claims 14-20. Moreover, claim 13 is included in the Section 103 rejection discussed below. Accordingly, Applicants do not know the status of claim 13. By this Response Applicants have cancelled claim 13. However, if the Examiner is indicating claim 13 as allowable, Applicants' request the Examiner to clarify his position so that Applicants can reinstate claim 13 in independent form if the subject matter is allowable.

In the Office Action dated February 26, 2002, the Examiner rejects claims 1-8 and 9-13 under 35 USC 103(a) as being unpatentable over Agarwal (6,218,256) in view of Tseng (6,291,343). Applicants respectfully disagree.

In summary, Applicants' process, in claim 3 as originally filed, recites "subjecting said barrier metal layer to an atmosphere chosen from the group consisting of: an ambient vacuum, hydrogen gas, argon gas, and helium gas." (emphasis added). (Applicants note that the "consisting of" language excludes any element, step or ingredient not specified in that element of the claim. MPEP, section 2111.03; *In re Gray*, 53 F.2d 520, 11 USPQ 255 (CCPA 1931); *Ex parte Davis*, 80 USPQ 448, 450 (Bd. App. 1948); *Mannesmann*

Demag Corp. v. Engineered Metal Products Co., 793 F.2d 1279, 230 USPQ 45 (Fed. Cir. 1986)). In contrast, Agarwal disclose subjecting a barrier layer to a reactive oxidizing gas to reduce the migration of contaminants between the dielectric layer and the electrode of a capacitor. Tseng disclose annealing a substrate, before deposition of the barrier layer thereon, to promote adhesion of the barrier layer to the substrate. Agarwal and Tseng, do not teach or suggest, either alone or in combination, a process of rapid thermal annealing a barrier layer in an atmosphere as claimed by Applicants. Applicants will now address in detail their process as claimed and the processes disclosed by the cited references.

Applicants' claim 1, as amended to include the limitation of claim 3 as filed, recites:

> "1. A method of pre-treating a barrier metal layer of a partially finished integrated circuit device prior to the deposition of a copper film thereon, comprising the steps of:
> providing a partially finished integrated circuit device including a barrier metal layer;
> subjecting said barrier metal layer to an atmosphere chosen from the group consisting of: an ambient vacuum, hydrogen gas, argon gas and helium gas;
> subjecting said barrier metal layer to a temperature greater than 200 degrees Celsius for at least thirty seconds to form a pre-treated barrier metal layer; and
> depositing a copper film on said pre-treated barrier metal layer."

Applicants' claim 9, as originally filed recites:

"9. A method of pre-treating a barrier metal layer of a partially finished integrated circuit device for the deposition of a copper film thereon, comprising the steps of:

providing a partially finished integrated circuit device including a barrier metal layer having a trench therein;

subjecting said barrier metal layer to a temperature greater than 200 degrees Celsius for at least thirty seconds in an atmosphere chosen from the group consisting of: an ambient vacuum, Hydrogen gas, Argon gas, and Helium gas to form a pre-treated barrier metal layer; and

thereafter depositing a copper film on said pre-treated barrier metal layer and throughout said trench."

As recited in Applicants specification, prior art pre-treatment processes "often result in variations in the deposited Cu film. These variations in the deposited Cu film are a severe problem which heretofore has hindered the application of CVD Cu films in IC processing." (Applicants' specification, page 2, lines 1-5). Applicants' process "eliminates variations in the deposited Cu film caused by Cu precursors" by providing "a rapid thermal process (RTP) wherein silicon wafers that are pre-coated with barrier metal films" are "pre-treated, prior to deposition of a copper film thereon, in a temperature range of between 300 and 550 degrees Celsius in a non-reactive gas such as hydrogen gas (H_2), argon (Ar), helium (He), or in an ambient vacuum," at a chamber pressure typically "between 0.1 mTorr and 20 Torr," and for a time period typically "between 30 to 100 seconds."

(Specification, page 2, lines 8-14) (emphasis added). None of the cited references teach or suggest Applicants process.

Agarwal teaches a process of oxygen annealing a barrier layer wherein the oxygen anneal:

> "establishes a concentration gradient profile for the transition from the dielectric to the electrode. Absent oxygen saturation of the barrier layer, oxygen from the dielectric might otherwise be attracted toward and diffuse into [the barrier layer] or overlying electrode layer 18, leaving vacancies within the dielectric. Additionally, the oxygen anneal is further theorized to help complete reaction of residual precursor elements within the refractory metal nitride layer, thereby removing accompanying contaminants, e.g., carbon, that might otherwise migrate as a contaminant into dielectric layer 14." (Agarwal, column 5, lines 52-63).

Accordingly, the entire purpose of Agarwal is to create an "oxygen rich" barrier layer to reduce migration of contaminants between the dielectric and the electrode. (Agarwal, column 2, lines 34-36). The oxidizing atmosphere utilized by Agarwal comprises "an oxidizing gas such as oxygen, ozone, or nitrous oxide." (Agarwal, column 2, lines 61-61). Nowhere in its specification does Agarwal teach or suggest conducting a rapid thermal anneal of the barrier layer in "an atmosphere chosen from the group <u>consisting of</u>: an ambient vacuum, hydrogen gas, argon gas and helium gas", as recited in Applicants claims 3 and 9 as originally filed. The only single mention of another gas is adding argon to the oxidizing gas: "the [barrier] layer is exposed to an atmosphere comprising an oxidizing gas of, for example,

oxygen, ozone or nitrous oxide ... To facilitate the anneal, a plasma excitation may be provided ... Additionally, an inert gas such as argon, may be included to bombard the barrier layer and further facilitate the plasma anneal." (Agarwal, column 9, lines 13-25). Addition of argon to Agarwal's reactive, oxidizing gas does not teach or suggest Applicants' "atmosphere chosen from the group consisting of: an ambient vacuum, hydrogen gas, argon gas and helium gas," (emphasis added) as recited in Applicants' claims 3 and 9 as filed.

The Examiner states that Agarwal teaches the specific process parameters of Applicants' process. In particular, the Examiner states that Agarwal teaches, in column 9, lines 13-25, the process parameters of a temperature range of 300-500 degrees Celsius and a pressure range of 0.01-1 atm. However, these temperature and pressure ranges are for an oxygen anneal conducted in "an atmosphere comprising an oxidizing gas of, for example, oxygen, ozone or nitrous oxide." Use of Applicants' non-reactive gases in the process of Agarwal would completely defeat the purpose of Agarwal in that no oxidizing of Agarwal's barrier layer would take place. The Examiner states that "Regarding claim 3, Agarwal teaches of exposing the barrier layer to an oxidizing gas at a vacuum and further provide the choice of adding Argon gas." The Examiner appears to completely ignore Applicants' claim language which recites "an atmosphere chosen from the group

consisting of: an ambient vacuum, hydrogen gas, argon gas and helium gas," (emphasis added) as recited in Applicants' claims 3 and 9 as filed. Moreover, the Examiner appears to ignore that the purposes of the two processes are vastly different. Agarwal teaches a process to oxidize a barrier layer in an oxidizing atmosphere so as to reduce the migration of contaminants between the dielectric and the electrode of a capacitor, whereas Applicants teach a process of annealing a barrier layer in a non-reactive atmosphere so as to increase the adhesion of a copper layer thereto. Agarwal's purpose and disclosed process is very different from, and does not teach or suggest, Applicants' process as recited in claims 3 and 9.

Tseng et al. teach a process of annealing a substrate to promote adhesion between the substrate and a barrier layer deposited on the substrate after the anneal. Tseng et al. mention barrier layers of refractory metals such as titanium nitride. However, Tseng do not teach or suggest a process of annealing the barrier layer to promote the adhesion of a copper layer to the barrier layer, as recited in Applicants' claims as filed. Moreover, Tseng et al. do not teach or suggest specific process parameters for conducting an anneal of a barrier layer. In particular, Tseng et al. teach:

> "the substrate is plasma annealed prior to the deposition of any film materials. During the plasma annealing, the substrate is bombarded with ions. After the substrate is plasma annealed, a layer of refractory metal nitride is deposited on

> the substrate. In one embodiment of the present invention, the refractory metal nitride is titanium nitride. As a result of plasma annealing the substrate, there is a good adhesive bond between the substrate and the refractory metal nitride." (Tseng et al., column 2, lines 44-52).

The Examiner states that Tseng et al. teach the process variables of Applicants process, and refers Applicants to the Tseng et al. specification: "see lines 49-51 of column 6". However, upon reading Tseng et al., it is very clear that the process variables listed in Tseng et al., and referred to by the Examiner, are for the anneal of the Tseng substrate, and not for anneal of the barrier layer: "In order to treat a substrate in accordance with the present invention..." (column 6, line 19); "With the showerhead 134 powered, [the disclosed process] is sufficient to attract nitrogen ions from the plasma 181 to impact the exposed substrate on the wafer 180" (column 6, lines 37-43); "When the substrate is tantalum pentoxide, the nitrogen bombardment, as described above, results in the formation of tantalum oxynitride on the upper surface of the exposed tantalum pentoxide substrate on the wafer 180" (column 6, lines 61-64); and, "Once the substrate has been treated by the plasma 181, a layer of a refractory metal nitride diffusion barrier material 182 is deposited on the upper surface of the wafer 180" (column 7, lines 37-39). None of the process variables recited by the Examiner in the Tseng et al. reference refer to a process for annealing the barrier layer. Instead, the process variables

cited by the Examiner are for conducting an anneal of the substrate itself, so as to promote adhesion of the barrier layer thereto.

Tseng et al. teach away from combining the process steps of Tseng et al. with those of Agarwal because Tseng et al. specifically recite that exposing the refractory metal barrier layer of Tseng et al. to an oxidizing atmosphere is undesirable: "This intermixing of the oxygen and the titanium nitride is undesirable, because the presence of oxygen raises the resistivity of the titanium nitride film." (Tseng et al., column 1, lines 65-67). Agarwal teach away from combining the process steps of Agarwal with those of Tseng et al. because the very purpose of the Agarwal process would be defeated by utilizing the atmosphere taught by Tseng et al.

Accordingly, the oxidizing process of Agarwal, wherein a barrier layer is saturated with oxygen, and the substrate anneal of Tseng et al. where a substrate is annealed prior to the deposition of a barrier layer thereon, are vastly different processes utilizing different chemical compounds, and are conducted on different components of the integrated circuit. One skilled in the art would not look to combine the process variables of Agarwal and Tseng et al. Moreover, neither Agarwal nor Tseng et al., either alone or in combination, teach or suggest annealing a barrier layer in a non-reactive "atmosphere chosen from the group consisting of: an ambient vacuum, hydrogen gas, argon gas and helium gas,"

as recited in Applicants' claims 3 and 9 as originally filed, and as in claim 1 as amended herein (to include the limitation of claim 3). Moreover, neither Agarwal nor Tseng et al., either alone or in combination, teach or suggest annealing a barrier layer in a non-reactive atmosphere with the process variables of time, temperature, and pressure, as recited in Applicants remaining dependent claims. For these reasons, Applicants request the Examiner to withdraw the rejection of independent claims 1 and 9 and corresponding dependent claims 2, 4-8 and 10-12, under 35 U.S.C. 103(a), and issue an allowance of these claims.

By this amendment, Applicants have added new claims 21 and 22. New claim 21 includes the limitations of claim 1 as filed, and further includes the limitation of subjecting the barrier metal film to a "non-reactive gas." Support for the additional limitation of new claim 21 is found in Applicants' specification as filed on page 2, lines 11-12, which recites that the barrier metal films are subjected to a rapid thermal process "in a non-reactive gas" such as hydrogen gas, argon, or helium, or in an ambient vacuum. Newly added dependent claim 22 recites the specific gases as recited in claim 3 as filed. For the above listed reasons, Applicants believe new claims 21 and 22 are allowable over the cited prior art and Applicants respectfully request allowance of these claims.

In view of the above noted amendments and remarks this application is believed to be in condition for allowance and

notice thereof is respectfully solicited. The Examiner is urged to contact Applicants' attorney at the number listed below if there are any questions.

Applicants respectfully request entry of this Amendment and consideration of the application as amended.

Respectfully submitted,

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Appendix A

Pages 16-17 of the present Response indicate the changes to the claims made herein in application Serial Number 09/820,068, filed March 28, 2001

Deleted material is indicated in brackets [ ] and
added material is underlined.

1. (First Amended) A method of pre-treating a barrier metal layer of a partially finished integrated circuit device prior to the deposition of a copper film thereon, comprising the steps of:

providing a partially finished integrated circuit device including a barrier metal layer;

<u>subjecting said barrier metal layer to an atmosphere chosen from the group consisting of: an ambient vacuum, hydrogen gas, argon gas and helium gas;</u>

subjecting said barrier metal layer to a temperature greater than 200 degrees Celsius for at least thirty seconds to form a pre-treated barrier metal layer; and

depositing a copper film on said pre-treated barrier metal layer.

3. Cancelled.

13-20. Cancelled.

21. (New Claim) A method of pre-treating a barrier metal layer of a partially finished integrated circuit device prior to the deposition of a copper film thereon, comprising the steps of:

providing a partially finished integrated circuit device including a barrier metal layer;

subjecting said barrier metal layer to a temperature greater than 200 degrees Celsius and to a non-reactive atmosphere for at least thirty seconds to form a pre-treated barrier metal layer; and

depositing a copper film on said pre-treated barrier metal layer.

22. (New Claim) The method of claim 21 wherein said non-reactive atmosphere is chosen from the group consisting essentially of: an ambient vacuum, hydrogen gas, argon gas and helium gas.